that *S. atrovirens* is morphologically variable; and Hicks (1928) has indicated that there is also substantial cytological variability. Some of this variability could be due to past hybridization of *S. atrovirens* with *S. ancistrochaetus*. — DEPARTMENT OF BOTANY, UNIVERSITY OF MICHIGAN, ANN ARBOR.

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# A SURVEY OF THE ALGAE OF LAKE QUINSIGAMOND[1]

TANG SHIH-CHEN AUYANG[2]

This study of the fresh water algae of Lake Quinsigamond, Worcester, Massachusetts, was undertaken in order to identify the species, to investigate their distribution, and to compare the results with those of G. E. Stone in his paper "Flora of Lake Quinsigamond" published in 1900.

Stone listed 81 genera and 331 species of algae, excluding Diatoms, in his paper; the Desmids (including placoderm and saccoderm types) were the largest group, totalling 150

[1]Portion of a thesis submitted to the Department of Biology, Clark University, in partial fulfillment of requirements for the degree of Master of Arts. The thesis was undertaken under the direction of Dr. Vernon Ahmadjian.

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species. The author found 86 genera and 217 species of algae, excluding Diatoms, in which only 66 species of Desmids were found. This great difference in the number of Desmid species can be explained possibly by the fact that external environment factors have changed during the past 60 years, and have inhibited the growth of these algae.

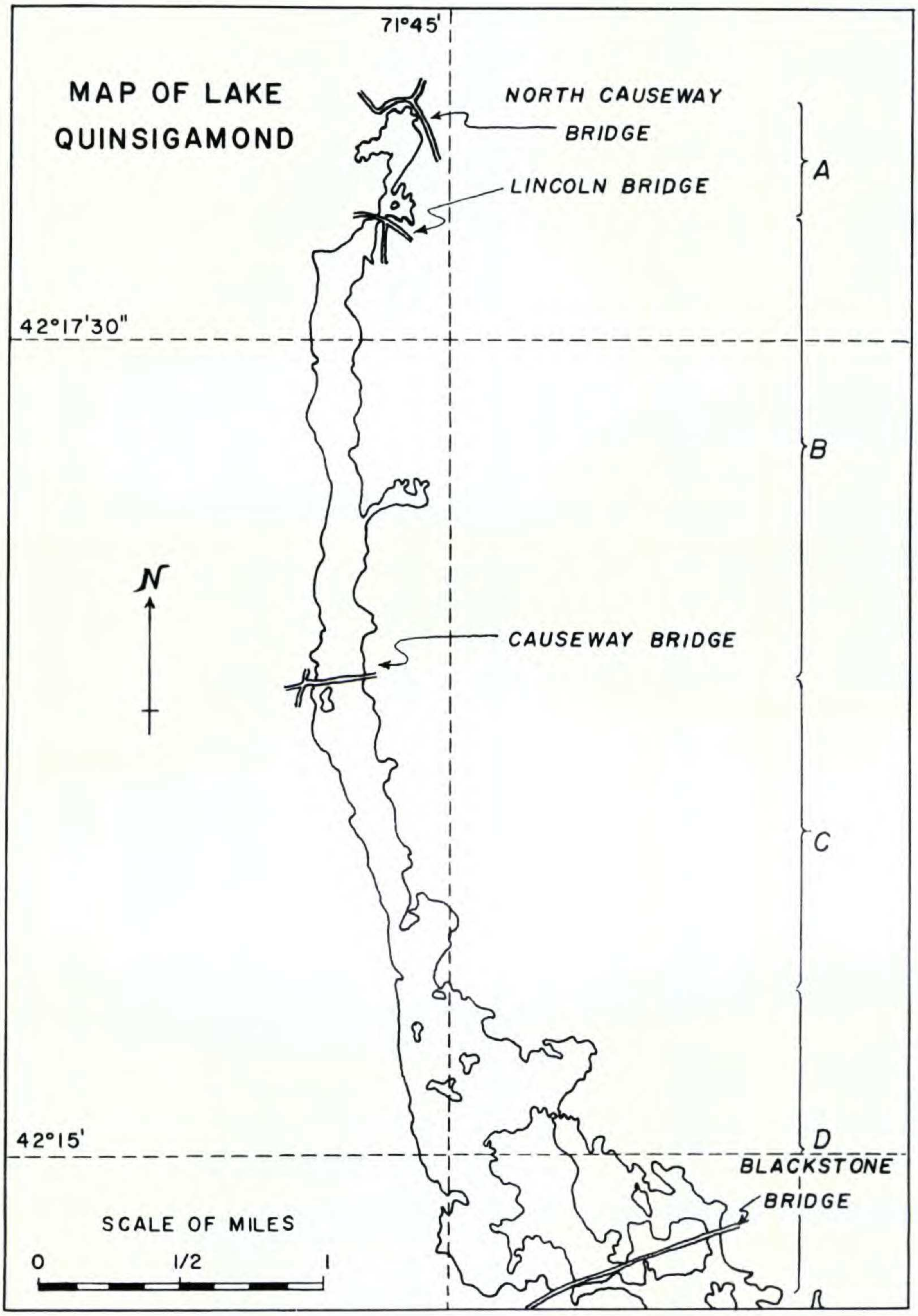
Probably as a result of these environmental changes, the author was not successful in collecting any species of *Chara* and *Nitella,* of which Stone found 5 and 6 species, respectively. On the other hand, tremendous quantities of *Hydrodictyon,* which was not listed in Stone's paper, were found by the author.

Thirty-nine genera listed by Stone were identified by the author. However, 42 genera which Stone found were not found by the author, while 47 genera, excluding Diatoms, not listed by Stone were collected and identified by the author. These figures show that the algal flora of Lake Quinsigamond has changed greatly due to factors which will require more detailed investigation by future workers.

The lake was described by Stone as follows: "Lake Quinsigamond which is situated near Worcester is one of the largest lakes in Massachusetts, and is about six miles long, hardly exceeding one-half mile in width, although in many places it is from fifty to one hundred feet or more in depth. It runs in a northerly and southerly direction along the edge of one of the geological dividing lines of the State which separates the central highlands from the less elevated areas of our seaboard. The immediate surroundings on the lake consist geologically of sand and gravel and probably the greater portion of the basin itself is made up of this material, over which there is spread a considerable mass of decomposed matter, the results of centuries of vegetable and animal decay. While a considerable portion of the basin of the lake is too deep to give rise to much vegetable life, there are vast areas of shallow water which are especially adapted to a profusion of vegetable forms, thus making it one of the best collecting grounds in Massachusetts."

PROCEDURE — The field work for this thesis started in

January, 1960. At that time, except for the northern inlet from which water flows into the lake, the whole lake was frozen with seven inches of ice covered with knee-deep



snow. In the beginning of April, ice on the lake gradually started to melt from north to south. By April, 5th, all of the ice had melted completely. While the lake was frozen, algae were collected within the limits of the northern inlet and samples were taken from a hole about 2 ft. in diameter dug through the ice in the middle of the lake. During the warmer, ice-free months, collections were made periodically either by walking along the lake shore or using a boat to travel to various parts of the lake.

DISTRIBUTION — Lake Quinsigamond can easily be divided into sections with the aid of four bridges; naming them from north to south, they are North Causeway Bridge, Lincoln Bridge, Causeway Bridge and Blackstone Bridge (Fig. 1).

1). At the North Causeway Bridge, *Draparnaldia* was very abundant. The water there was clear and running and its temperature was about 1.5 C° when collections were made. *Draparnaldia* was found attached to small stones under the bridge. In the quiet water near the shore many specimens of *Tetraspora* were found. Planktonic collections in this area contained large numbers of desmids, diatoms and several species of *Pediastrum* in early spring.

2). Under Lincoln Bridge there were a few big rocks on which *Ulothrix*, in the vegetative stage, was collected in the early months of spring, when the water was 4.0 C°. The abundance of *Ulothrix* decreased gradually, disappearing almost entirely in the early summer. Collections in late spring also contained *Zygnema*, in the vegetative stages, intermingled with *Spirogyra*, *Tolypothrix*, *Oscillatoria* and *Rhizoclonium*.

From late summer to fall the region between these two bridges was covered by a mat of *Hydrodictyon*, *Spirogyra* and other filamentous algae.

3). On the east side of Causeway Bridge, the clear water ran slowly and contained *Stigeoclonium* attached to submerged aquatics growing near the shore in late spring. At the same time, about two miles south of the bridge and also on the east shore, *Vaucheria* was found in fruiting stages in the shallow, sandy bottom.

North and south of this bridge as far down as Blackstone Bridge on the east bank, the red alga *Batrachospermum* was found in scattered localities. This alga grew in clusters on small stones near the shore and produced fruiting bodies in June.

On the west shore, half a mile south of the bridge, the water near the shore and farther away from it contained abundant nets of *Hydrodictyon*. Collections from the surface water as well as below contained this alga, after the beginning of June.

4). The water north of the Blackstone Bridge and especially just beneath the bridge contained abundant specimens of species of *Polycystis, Coelosphaerium* and *Anabaenopsis*. A small dam south of the bridge retarded the water flow, and probably caused the great accumulation of these forms under it. The "water bloom" of this region was observed in the fall.

Generally speaking, the filamentous green algae such as *Spirogyra, Mougeotia* and *Oedogonium* were widespread and long-lasting in occurrence. Mostly the vegetative stages were observed and only few of these algae were in reproductive stages when collected.

*Lyngbya*, a filamentous blue-green alga, was collected from May to autumn in many regions but especially at the Lincoln Bridge, where great masses were found in the fall.

The many other algae, unicellular, colonial and multicellular which are recorded in other parts of this paper were of widespread occurrence, either in the plankton, attached to submerged objects, or free floating on the surface. The vegetative stages of these algae and occasionally the reproductive stages were observed in fresh collections.

## ALPHABETICAL LIST OF SPECIES

Amphora ovalis Kützing
Anabaena limnetica G. M. Smith
A. variabilis Kützing
A. viguieri Denis & Frémy
Anabaenopsis elenkinii Miller
Ankistrodesmus convolutus Corda
A. falcatus (Corda) Ralfs
A. falcatus var. acicularis (A. Braun) G. S. West
Aphanocapsa grevillei (Hass.) Rabenhorst
Aphanochaete repens A. Braun
Aphanothece clathrata G. S. West
A. microscopica Nägeli

A. stagnina (Spreng.) A. Braun
Asterionella formosa Hassall
A. gracillima (Hantzsch) Heiberg
Batrachospermum vagum (Roth) C. A. Agardh
Bulbochaete repanda Wittrock
B. scrobiculata (Tiff.) Tiffany
Bumilleria sicula Borzi
Caloneis silicula (Ehrenb.) Cleve var. inflata (Grun.) Cleve
Calothrix stellaris Bornet & Flahault
Ceratium hirundinella (O.F.M.) Schrank
Characiopsis acuta (A. Braun) Borzi
Chlamydomonas angulosa Dill
C. mucicola Schmidle
C. polypyrenoideum Prescott
C. snowii Printz
C. sphagnicola Fritsch & Takeda
Chlorella ellipsoidea Gerneck
C. vulgaris Beijerinck
Chlorococcum humicola (Näg.) Rabenhorst
Chroococcus limneticus Lemmermann
Closterium acerosum (Schrank) Ehrenberg
C. calosporum Wittrock
C. dianae Ehrenberg
C. didymotocum Ralfs
C. ehrenbergii Meneghini
C. incurvum de Brébisson
C. lagoense Nordstedt
C. lanceolatum Kützing
C. leibleinii Kützing
C. lunula (Müller) Nitzsch
C. moniliferum (Bory) Ehrenberg
C. turgidum Ehrenberg
C. sigmoideum Lagerheim & Nordstedt
Coelastrum microporum Nägeli
Coelosphaerium dubium Grunow
C naegelianum Unger
Coleochaete orbicularis Pringsheim
C. scutata de Brébisson
C. soluta (de Bréb.) Pringsheim
Cosmarium biretum de Brébisson var. trigibberum Nordstedt
C. broomei Thwaites
C. botrytis Meneghini
C. dentiferum Corda
C. formosulum Hoffman
C. formosulum var. nathorstii (Boldt) W. & G. S. West
C. granatum de Brébisson
C. margaritatum Roy & Biss.
C. monomazum Lundell
C. nitidulum DeNotaris
C. orbiculatum Ralfs
C. panamense Prese
C. protractum (Näg.) DeBary
C. pseudoconnatum Nordstedt
C. punctulatum de Brébisson
C. quadrum Lundell
C. reinforme (Ralfs) Archer
Cosmocladium hitchcockii (Wolle) G. M. Smith
Crucigenia truncata G. M. Smith
Cyclotella bodanica Eulenstein
C. bodanica var. stellata Skvortzow
C. comta (Ehrenb.) Kützing
Cymbella aspera (Ehrenb.) Cleve
C. tumida (de Bréb.) Van Heurck
Desmidium swartzii C. A. Agardh
Diatoma hiemale (Lyngbye) Heiberg var. mesodon (Ehrenb.) Grunow
D. vulgare Bory
Dinobryon sertularia Ehrenberg
Dictyosphaerium pulchellum Wood
Draparnaldia glomerata (Vauch.) C. A. Agardh
D. judayi Prescott
Epithemia turgida (Ehrenb.) Kützing
Euastrum elegans (de Bréb.) Kützing
E. pulchellum de Brébisson
E. verrucosum (Ehrenb.) Ralfs
Euglena gracilis Klebs

E. spirogyra Ehrenberg
Fragilaria capucina Desmazieres
F. construens (Ehrenb.) Grunow
F. crotonensis Kitton
F. crotonensis var. prolongata Grunow
Gloeocystis ampla (Kütz.) Lagerheim
G. gigas (Kütz.) Lagerheim
G. major Gerneck ex Lemmermann
G. vesiculosa Nägeli
Golenkinia paucispina W. & G. S. West
Gomphoneis herculeana (Ehrenb.) Cleve var. robusta (Grun.) Cleve
Gomphonema acuminatum Ehrenberg
G. constrictum Ehrenberg
Gonatozygon kinahani (Arch.) Rabenhorst
Gymnodinium fuscum (Ehrenb.) Stein
G. palustre Schilling
Hormidiopsis ellipsoideum Prescott
Hyalotheca dissiliens (J. E. Smith) de Brébisson
Hydrodictyon reticulatum (L.) Lagerheim
Kirchneriella lunaris (Kirch.) Moebius var. irregularis G. M. Smith
Leptosira mediciana Borzi
Licmophora gracilis (Ehrenb.) Grunow
L. paradoxa (Lyngbye) C. A. Agardh
Lyngbya epiphytica Hieronymus
L. latissima Prescott
L. majuscula (Dill.) Harv.
L. wollei Farlow
Merismopedia punctata Meyen
Melosira italica (Ehrenb.) Kützing
M. juergensii C. A. Agardh
Micrasterias americana (Ehrenb.) Ralfs
M. apiculata (Ehrenb.) Meneghini
M. apiculata var. fimbriata (Ralfs) Nordstedt f. spinosa (Bissett) W. & G. S. West
M. radiata Hassall
M. rotata (Grev.) Ralfs
M. truncata (Corda) de Brébisson
Microspora willeana Lagerheim
Microthamnion kuetzingianum Nägeli
Mougeotia capucina (Bory) C. A. Agardh
M. floridana Transeau
M. genuflexa (Dillw.) C. A. Agardh
M. laetevirens (A. Braun) Wittrock
M. parvula Hassall
M. reinschii Transeau
M. robusta (de Bary) Wittrock
M. scalaris Hassall
Mougeotiopsis calospora Palla
Navicula anglica Ralfs
Netrium digitus (Ehrenb.) Itsigsohn & Roth
Nostoc muscorum C. A. Agardh
Oedogonium borisianum (Le Cl.) Wittrock
O. capillare (L.) Kützing
O. crenulatocostatum Wittrock
O. grande Kützing var. aequatoriale Wittrock
O. laeve Wittrock
O. plusiosporum Wittrock
O. pringsheimii Cramer
Oöcystis pusilla Hansgirg
Oscillatoria cortiana Meneghini
O. curviceps C. A. Agardh
O. ornata Kützing
O. prolifica (Grev.) Gomont
O. splendida Greville
O. tenuis C. A. Agardh
Pandorina morum (Muell.) Bory
Pediastrum biradiatum Meyen

P. boryanum (Turp.) Meneghini
P. boryanum var. longicorne Raciborski
P. duplex Meyen
P. duplex var. clathratum (A. Braun) Lagerheim
P. duplex var. rotundatum Lucks
P. duplex var. rugulosum Raciborski
P. ehrenbergii A. Braun
P. tetras (Ehrenb.) Ralfs
P. tetras var. tetraodon (Corda) Rabenhorst
Penium margaritaceum (Ehrenb.) de Brébisson
P. digitus (Ehrenb.) Itsigsohn & Roth
Peridinium cinctum (Müll.) Ehrenberg
Phacus longicauda (Ehrenb.) Dujardin
Phormidium nareanum Grunow
Pinnularia nobilis Ehrenberg
Planktosphaeria gelatinosa G. M. Smith
Pleurotaenium coronatum (de Bréb.) Rabenhorst
P. maximum (Reisch) Lund
P. trabecula (Ehrenb.) Nägeli
Polycystis aeruginosa Kützing
P. incerta Lemm.
Pleurococcus vulgaris Nägeli
Protoderma viride Kützing
Radiofilum flavescens G. S. West
Rhizochrysis limnetica G. M. Smith
Rhizoclonium hieroglyphicum (C. A. Ag.) Kützing
R. hieroglyphicum var. hosfordii (Wolle) Collins
R. hookeri Kützing
Scenedesmus abundans (Kirch.) Chodat
S. abundans var. brevicauda G. M. Smith
S. acutiformis Schroeder
S. arcuatus Lemmermann var. platydisca G. M. Smith
S. armatus (Chod.) G. M. Smith var. major G. M. Smith
S. bijuga (Turp.) Lagerheim
S. brasiliensis Bohlin
S. denticulatus Lagerheim
S. dimorphus (Turp.) Kützing
S. longus Meyen
S. longus var. minutus G. M. Smith
S. obliquus (Turp.) Kützing
S. quadricauda (Turp.) de Brébisson
S. quadricauda var. longispina (Chod.) G. M. Smith
Sorastrum americanum (Bohlin) Schmidle
Sphaeroceptis schroeteri Chodat
Spirogyra cleveana Transeau
S. ellipsospora Transeau
S. hydrodictya Transeau
S. jugalis (Fl. Dan) Kützing
S. mirabilis (Hass.) Kützing
S. nitida (Dillw.) Link
S. submaxima Transeau
Spirotaenia condensata Brébisson
Spirulina duplex Wolle
Spondylosium pulchellum Arch.
Staurastrum alternans de Brébisson
S. avicula de Brébisson
S. brevispinum de Brébisson var. tumidum G. M. Smith
S. cerastes Lund
S. crenulatum (Delp.) Nägeli
S. dickiei Ralfs var. maximum W. & G. S. West
S. dilatatum Ehrenberg
S. furcigerum de Brébisson
S. gracile Ralfs
S. grande Bulnheim
S. leptocladum var. denticulatum G. M. Smith
S. odontatum Wolle
S. orbiculare (Ehrenb.) Ralfs
S. paradoxum Meyen

S. subgrande Borge var. minus G. M. Smith
Stauroneis acuta W. Smith
Stigeoclonium flagelliferum Kützing
S. nanum Kützing
Surirella elegans Ehrenberg
S. splendida (Ehrenb.) Kützing
Synechocystis aquatilis Sauvageau
Synedra ulna (Nitzsch) Ehrenberg
S. ulna var. aequalis (Kütz.) Hustedt
Synura uvella Ehrenberg
Tabellaria fenestrata (Lyngb.) Kützing
T. flocculosa (Roth) Kützing
Tetraëdron limneticum Borge
Tetraspora cylindrica (Wahl.) C. A. Agardh
T. lubrica (Roth) C. A. Agardh
Tetrastrum staurogeniaeforme (Schroeder) Lemmermann
Tolypothrix conglutinata Borzi
T. distorta Kützing
lanata Wartmann
Trachelomonas crebea (Kellicott) Deflandre
Tribonema bombycinum (C. A. Ag.) Derbés & Solier
Ulothrix tenerrima Kützing
U. zonata (Weber & Mohr) Kützing
Vaucheria ornithocephala C. A. Agardh
V. sessilis (Vauch.) DeCandolle
Westella linearis G. M. Smith
Xanthidium antilopaeum (de Bréb.) Kützing var. polymazum Nordstedt
Zygnema insigne (Hass.) Kützing

The following is an alphabetical list which shows the genera found by both Stone and the author, and those found only by Stone or by the author.

| Stone and author | Stone | Author |
| --- | --- | --- |
| Anabaena | Arthrodesmus | Anabaenopsis |
| Aphanochaete | Bambusina | Ankistrodesmus |
| Batrachospermum | Botrydium | Aphanocapsa |
| Bulbochaete | Calocylindrus | Aphanothece |
| Calothrix | Chaetophora | Bumbilleria |
| Closterium | Chara | Ceratium |
| Coelastrum | Characium | Characiopsis |
| Coelosphaerium | Chlamydococcus | Chlamydomonas |
| Coleochaete | Chroolepus | Chlorella |
| Cosmarium | Cladophora | Chlorococcum |
| Desmidium | Clathrocystis | Chroococcus |
| Dictyosphaerium | Conferva | Cosmocladium |
| Draparnaldia | Craterospermum | Crucigenia |
| Euastrum | Cylindrocapsa | Dinobryon |
| Euglena | Cylindrospermum | Golenkinia |
| Gloeocystis | Dimorphococcus | Gonatozygon |
| Hyalotheca | Docidium | Gymnodinium |
| Lyngbya | Eremosphaera | Hormidiopsis |
| Micrasterias | Gloeotrichia | Hydrodictyon |
| Microthamnion | Gonium | Kirchneriella |

| | | |
|---|---|---|
| Nostoc | Hapalosiphon | Leptosira |
| Oedogonium | Hydrurus | Merismopedia |
| Oscillatoria | Isactis | Microspora |
| Pandorina | Leptothrix | Mougeotia |
| Pediastrum | Mesocarpus | Mougeotiopsis |
| Penium | Mesotaenium | Netrium |
| Pleurococcus | Nephrocytium | Oöcystis |
| (Protococcus) | Nitella | Peridinium |
| Rhizoclonium | Ophiocytium | Phacus |
| Scenedesmus | Palmella | Phormidium |
| Sorastrum | Pleurocarpus | Planktosphaeria |
| Spirogyra | Polyedrium | Pleurotaenium |
| Stigeoclonium | Porphyridium | Protoderma |
| Staurastrum | Raphidium | Polycystis |
| Tetraspora | Rivularia | Radiofilum |
| Tolypothrix | Schizochlamys | Rhizochrysis |
| Ulothrix | Scytonema | Sphaerocystis |
| Vaucheria | Sirosiphon | Spirotaenia |
| Xanthidium | Sphaerozosma | Spirulina |
| Zygnema | Stauraspermum | Spondylosium |
| | Tetmemorus | Synechocystis |
| | Volvox | Synura |
| | | Tetraëdron |
| | | Tetrastrum |
| | | Trachelomonas |
| | | Tribonema |
| | | Westella |

Diatoms excluded from above lists.

DISCUSSION — It is possible that some of the differences in the algae collected by Stone and the author may be due to the fact that Stone listed algal names now regarded as synonymous. This may be one explanation as to the great difference in the number of species listed by the author. However, the difference in the number of Desmid species, especially, cannot be due solely to differences in nomenclature. The reason why the number of species, especially Desmids, decreased between 1900-1960 could be because the environmental conditions in Lake Quinsigamond have changed.

The chief environmental factors are light, temperature, chemical composition and pH of water. The first two factors were not recorded in Stone's paper. Therefore, there is no way to compare and discover what changes have occurred in these two factors from 1900 to 1960. However, there is at least one external environmental factor which has been introduced on the lake during this 60-year period, and that is the presence of motor boats. Outboard motor boats deposit a film of oil on the surface of the lake. This oil is then moved, by the motion of waves, to the shores or coves. These coves are the best habitats for the planktonic Desmids. If the water is covered with an oily film, atmospheric oxygen cannot dissolve into the water and as a result the respiration of Desmids will eventually cease. This unfavorable environment probably inhibited growth of certain Desmids.

Five species of *Chara* and six species of *Nitella* were found by Stone. The author was not successful in collecting any species of these genera. One possible reason is that "*Chara* thrive best in clear, hard water (Smith 1950)." The Health Department of Worcester stated that in 1945 the water in Lake Quinsigamond was quite soft, the hardness being 23. It may be that the water today exhibits an even lower degree of hardness due to factory pollutions (personal communication, Health Department, Worcester, Mass.). However, this fact has not been substantiated either by the Worcester Health Department or by the author. Another possible reason is that there are many ducks on the lake and they feed upon these algae.

The range of pH values of water samples in Lake Quinsigamond was 6.5-7.8. However, there was one exception, namely, the water sample taken from the west shore, one half mile south of Causeway Bridge. This water in which tremendous quantities of *Hydrodictyon* were found has a pH of 9.0 in June. It is interesting to note that this finding supports the following statement: "*Hydrodictyon* may be used as an index organism for a high pH (Prescott, 1951)."

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